DEPARTMENT OF THE ARMY PERMIT APPLICATION
APRIL 2020

COLLIER COUNTY
COMPREHENSIVE WATERSHED IMPROVEMENT PLAN
COLLIER COUNTY, FLORIDA

SUPPLEMENTAL INFORMATION
ATTACHMENT 11
WATER QUALITY ANALYSIS

Collier County Comprehensive Watershed Improvement Plan Project

Supplemental Information Attachment 11

CWIP Project Water Quality Analysis

Summary

The data and related analyses described below suggest

1. The water withdrawn from the Golden Gate Canal to rehydrate the project area and the I-75 runoff water that will unavoidably enter the system at the same time has nutrient and total suspended solids concentrations above expected project area background values.
2. Proposed treatment of influent water quality should provide a significant water quality benefit.
3. The water that enters the project effects area is expected to be close to background values and the receiving wetlands should assimilative the remaining additional nutrients within the first 600 acres of the 9,002 acres project effects area.

The water quality analyses are split into three sections:

Collier County Comprehensive Watershed Improvement Plan Project

Supplemental Information Attachment 11: Water Quality Analyses

Section 1. Water Quality Concentration Estimates

Introduction

The water to enhance the hydrologic conditions in the CWIP project area will come from the Golden Gate Canal, a regional stormwater drainage canal in Collier County. Runoff from I-75 in the project area will also (unavoidably) enter the inflow stream. This section provides:

- Estimated water quality concentrations of the GGC waters and I-75 runoff water
- Estimated background water quality in the Picayune Strand State Forest project area

Water quality obtained from public databases and technical literature provided the basis for the water quality concentration estimates for total phosphorus (TP), total nitrogen (TN) and total suspended solids (TSS). Golden Gate Canal water quality data were obtained from STORET SPA database (FDEP 2019a) and WIN/STORET database (FDEP 2019b). The GGC@White water quality monitoring station is located just upstream of the project water withdrawal location. The data from that site span a period from late 2009 through early 2019. TP, TKN, Nitrite+Nitrate and TSS are reported here as they are the typical focus of water quality treatment in Florida. Background concentrations were assumed similar to those in the Big Cypress Basin natural area and obtained from the technical literature. I-75 roadway runoff was estimated from technical literature as well.

Golden Gate Canal and Big Cypress Basin Water Quality

<u>Golden Gate Canal TP</u>

TP was measured on 100 dates between October 2009 and April 2019 at GGC@White Station. Basic statistical analysis was performed. The median value was 20 ug/L, and the mean only slightly higher (**Table 1**). Only two values exceeded Tukey's Fences (Tukey, 1977), the whiskers in Figure 1, TP Box and Whisker Plot. The fences provide a non-parametric exploratory data analysis tool to identify potential data outliers. Seven values above 0.037 mg/L exceeded the 90th percentile of all values (Figure 2). Eighty-eight percent of TP data from GGC@White were 0.03 mg/L or less (Figure 2).

Table 1. Total Phosphorus Statistics, Station GGC@White on Golden Gate Canal and BCB Interior (Miller et al. 2004).

Statistic	GGC value mg/L	BCB Value mg/L
Minimum	0.004	
First Quartile	0.016	
Median	0.020	0.011
Average	0.0228	0.00.1212
Third Quartile	0.029	
Maximum	0.079	

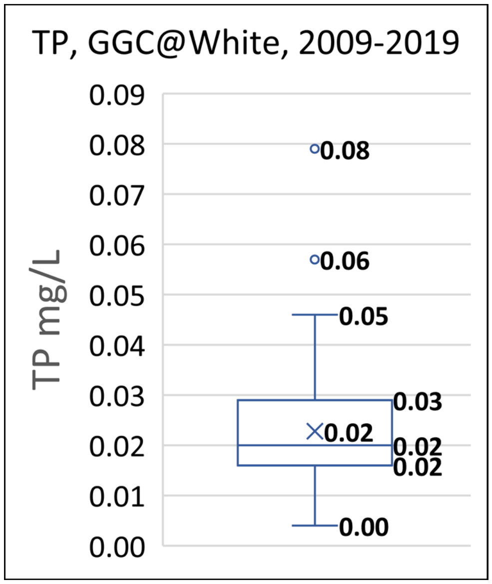

Figure 1. Box and Whisker Plot of TP, Golden Gate Canal at Station GGC@White, values in mg/L

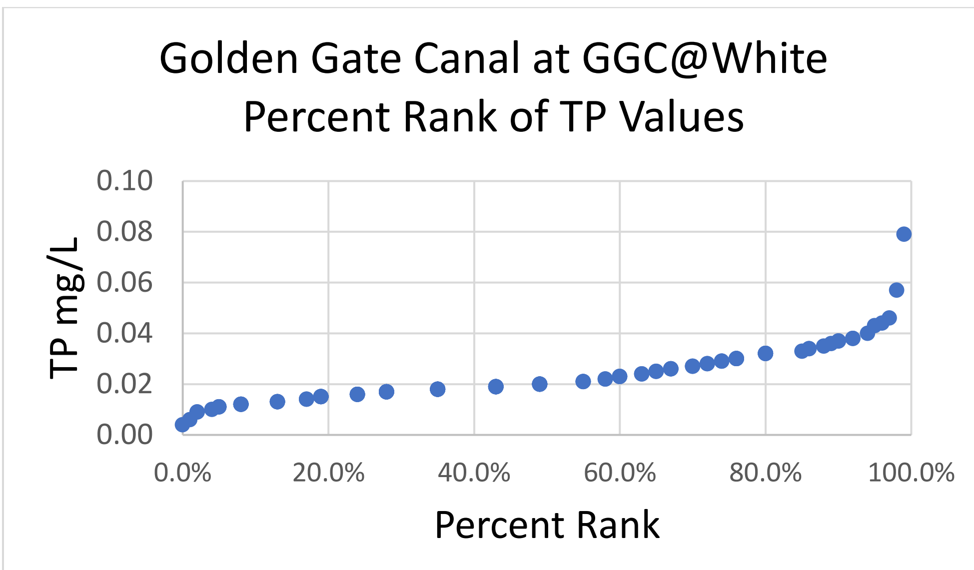

Figure 2. Percent Ranking of TP Values, Station GGC@White

<u>Big Cypress Basin TP</u>

The data available from the Big Cypress Basin is the closest readily available background information for comparison to expected water quality in the interior of the Belle Meade Flowway. The ecosystem in the Belle Meade Flowway, dominated by Cypress and Cypress-Pine-Cabbage Palm communities is somewhat different from the ecosystem described in Miller et al (2004) as “cypress domes, elongated bands of cypress trees called strands, and meandering marshy areas called sloughs”. The Belle Meade Flowway has no significant slough habitat and is better characterized as a basin swamp, with large areas of highly dissected wetland forest habitats. There is no large marshy area in the Belle Meade Flowway. The similarities include the shallow soils underlain by limestone, rainfall climate, dominant species (Cypress) and sheetflow hydraulics.

Miller et al (2004) concluded that “Ninety percent of TP concentrations [at outflows from Big Cypress Basin] were less than 0.03 mg/L”. Figure 3, from Miller et al, shows median TP concentrations at various locations in the Big Cypress National Preserve (well east of the Belle Meade Flowway) ranging from 0.019 to 0.009 mg/L. The report states that:

> Median concentrations of TP generally were higher in BICY than in EVER and its adjacent canals (fig. 17). Several possible sources for the high concentrations in BICY include: (1) high phosphorus content in surficial (in or near the land surface) rocks, soils, or ground water; (2) a larger release or smaller uptake of phosphorus by soils and vegetation of the Big Cypress Swamp compared with the Everglades; (3) shallower water, less flow, and more ponding in Big Cypress Swamp that could favor chemical or biological processes that increase phosphorus release to the water, or simply accumulation of higher concentrations of waste from wildlife; or (4) an influence from high-phosphorus canal waters near the Preserve boundaries. For example, sites A1 and A2 have high median concentrations and are near the northwestern boundary and the Barron River Canal, and sites A5, A6, and A9 also have high median concentrations and are near the eastern boundary and the L-28 canal system. Miller and others (1999, fig. 7) found a general east-to-west increase in TP in water along the Tamiami Canal in the wet and dry seasons, and this suggests that surficial geology may be a dominant influence. (Miller et al. 2004: p. 19)

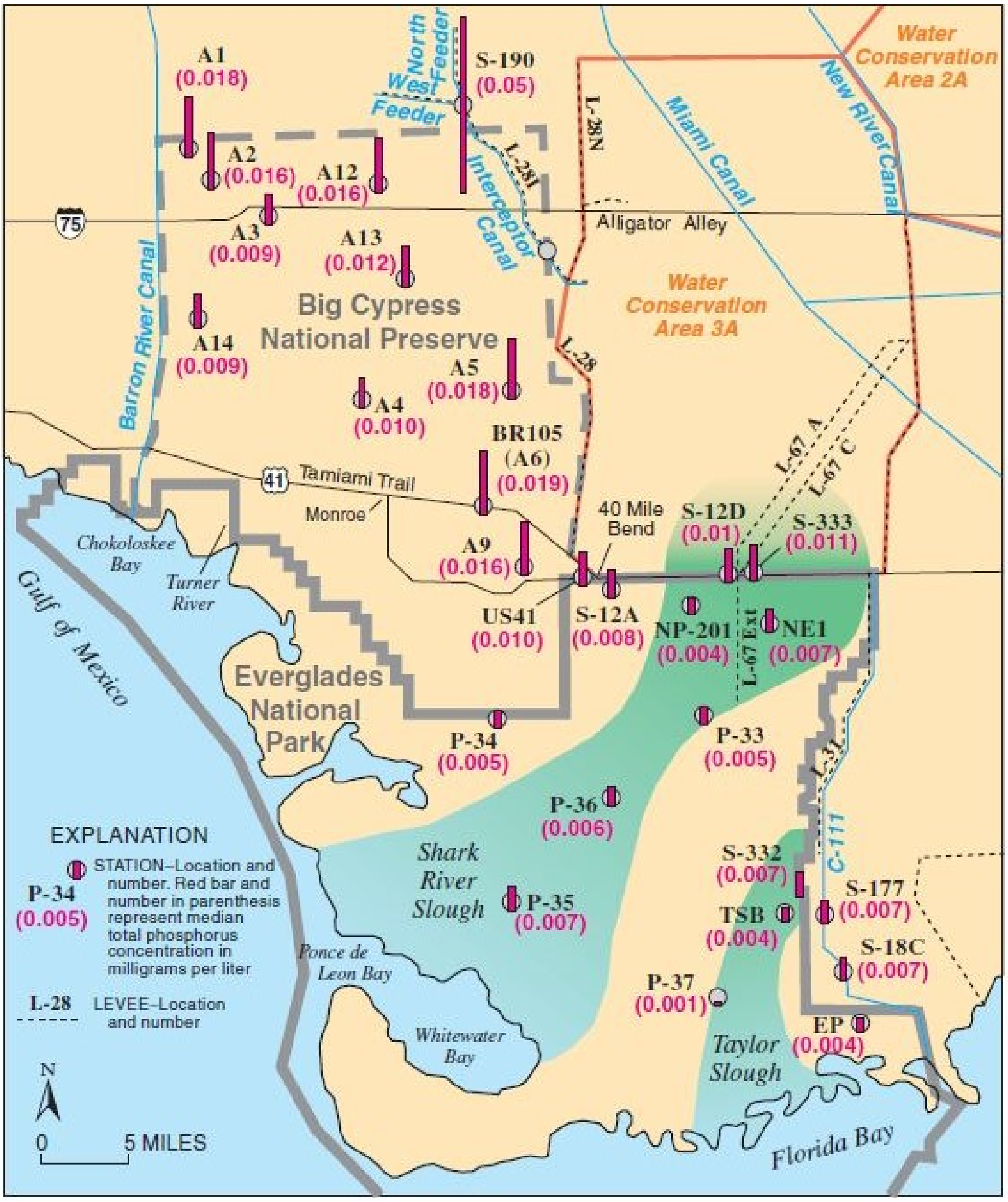

Figure 17. Median total phosphorus concentrations at Big Cypress National Preserve and Everglades National Park sites and nearby canal sites, 1991-2000.

Figure 3. Water Quality Summary Data from Big Cypress Basin: Figure 17 from Miller et al.

SFWMD (2009: Section 4: Descriptions of Picayune Strand Watershed and Valued Ecosystems) reported that “data from monitoring sites located at the inflows of the project area along the Faka Union and Merritt Canals indicate mean phosphorus concentrations of 15 parts per billion (ppb) (USACE and SFWMD 2004). The estuarine sampling site located at the outfall of the Faka Union Canal weir averaged 20 ppb”. Averaging the data provided in Miller et al provided a background concentration of 0.013 mg/L, which was selected for use in water quality calculations.

<u>GGC Canal Nitrogen</u>

Total Kjeldahl Nitrogen (TKN) and NO2+NO3 (NOx) from Station GGC@White 2009 – 2019) reported in WIN/STORET and SPA (**Table 2**, **Figures 4, 5, and 6**) were compared to similar data reported in Miller et al (2004: Figure 7). The median of Golden Gate Canal summed TKN and NOx values, 0.880mg/L was very similar to the median total nitrogen (TN) values reported for Big Cypress Basin and Everglades National Park (**Table 4**) Miler et al (2004) reported "Median concentrations of TN ranged from 0.64 to 1.8 mg/L; there were no obvious patterns between canals and interior sites or across the landscape (Figure 5: from Miller et al 2004 Fig. 18). Median TKN+NOx value for data available 2009-2018 at Station GGC@White (0.88, Figure 6) was toward the lower end of the values reported by Miller et al (Figure 7).

Table 2. TKN+NOX values for GGC Canal (2009-2019) and BCB (Miller et al 2004)

TKN+NOx Statistic	Value GGC Canal mg/L	Value BCB Interior mg/L
Minimum	0.328	
1st quartile	0.735	
Median	0.880	0.900 (TN)
Mean	0.910	0.917 (TN)
3rd quartile	1.086	
maximum	1.996	

<u>Big Cypress Basin Nitrogen</u>

Median concentration of GGC NOx values, 0.038 mg/L (**Figure 5**), were higher than those reported for Big Cypress Basin interior stations: "median concentrations at most sites in the interior (of Big Cypress Basin Preserve and Everglades National Park) were less than 0.01 mg/L"; The NOx values tended to be higher in C-111 canals". The authors speculated that reasons for the higher inorganic nitrogen in the canals might include: (1) less biological uptake in the canals due to less contact with vegetation and bottom sediments and their associated micro-organisms, (2) greater inputs of ground water enriched in inorganic nitrogen into canals than into marshes, or (3) greater inputs of fertilizers to canals because of proximity to agriculture". (Miller et al 2004: p. 24 and Figure 19). The GGC canals drain
large residential areas and agricultural land uses which may similarly contribute nitrogen fertilizers.

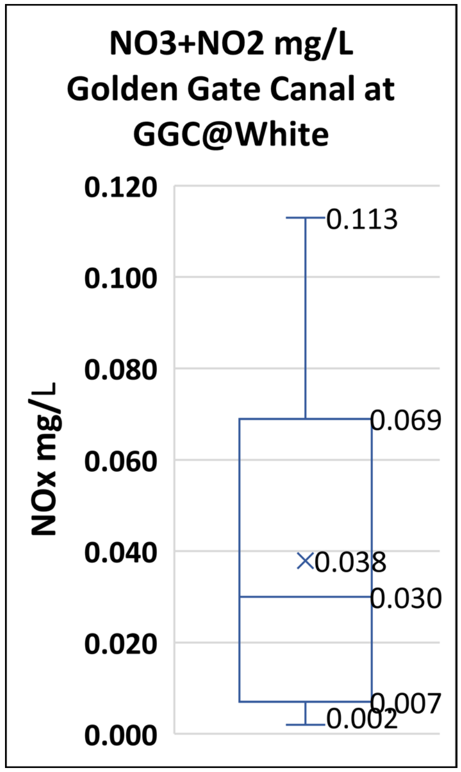

Figure 5. NO_2+NO_3 (NOx) at Station GGC@White, Golden Gate Canal

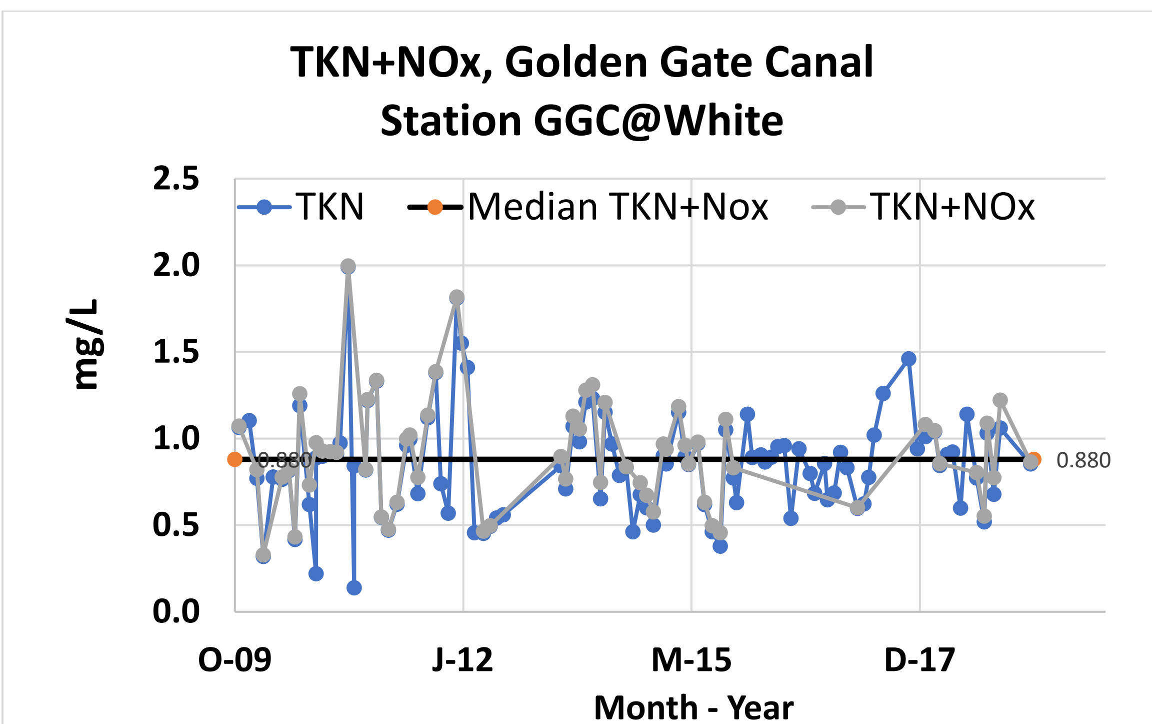

Figure 6. TKN and TKN+NOx (NO_2+NO_3), Golden Gate canal at Station GGC@White, October 2009- December 2018

For use in determining potential water quality effects of the project, we selected the mean values for TN from the GGC and BCB data **(Table 2)**; the available data suggest that (1) the total nitrogen in the Golden Gate Canal at GGC@White and the interior of BCB are very little different. The concentration of NOx in the GGC water is likely higher than that component of BBC interior waters. However, the GGC NOx values are not at levels that would cause concern and will be quickly taken up by bacteria and vegetation.

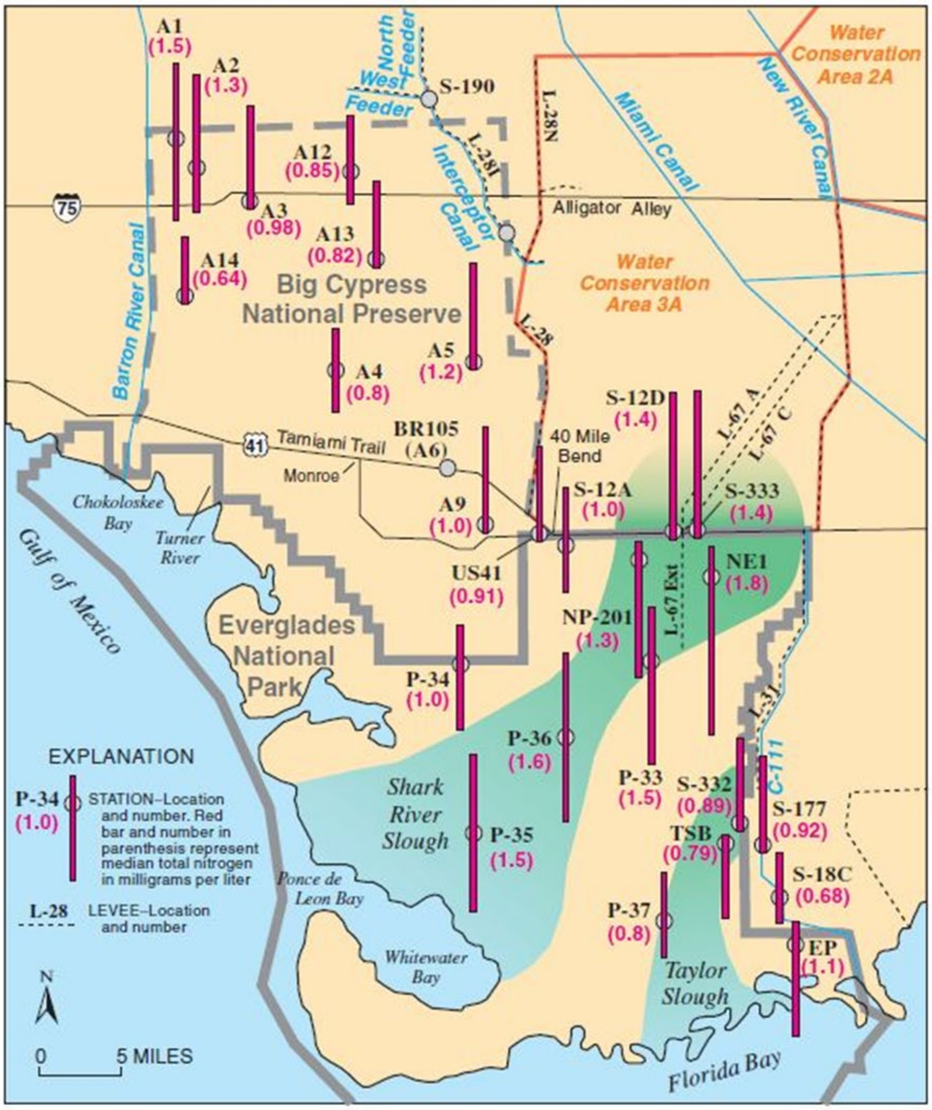

Figure 18. Median total nitrogen concentrations at Big Cypress National Preserve and Everglades National Park sites and nearby canal sites, 1991-2000.

Figure 7. Median Total Nitrogen (TN) concentrations from Miller et al (2004)

Golden Gate Canal TSS

Total Suspended Solids (TSS) is a more difficult parameter to characterize. The GGC data are mostly (~75%) "non-detect" values, reported as the minimum detection limit for the sample. There are relatively few large studies of TSS in wetland forested systems to use as a comparison to the GGC data, and the dataset available in Miller et al (2004), used to identify background values for phosphorus and nitrogen, did not include TSS.

Big Cypress Basin TSS

Miller et al (2004) did not report TSS values in the BCB interior. Hand (2004) reported a median TSS value = 4 mg/L for Florida blackwater systems. Atkins North America (2011) reported TSS statistics for several Watersheds in Collier county (**Table 3**) and compared them to screening level standards based on the 70th % value of all available data (Friedman and Hand 1998). They reported a TSS screening value standard of 7 mg/L.

Table 3. Estimates of Total Suspended Solids Values for Wetlands in Southwest Florida

Watershed	Sample (n)	Min (mg/L)	Average (mg/L)	Median (mg/L)	Max mg/L	Exceedance *(%)
Faka Union	441	2.0	3.1	2.0	62.0	6
Fakahatchee	368	2.0	4.8	2.0	97	10
Rookery Bay	122	2.0	3.6	2.0	56	6
Golden Gate-Naples Bay	478	2.0	3.7	2.0	94	5
Okaloaccoochee/SR29	238	2.0	4.6	4.0	174	5

*Exceedence = Exceedence of Class III Freshwater quality standard F.A.C. 62-302-530) = 7.0 mg/L for streams

Total suspended solids (TSS) data from GGC@ White (**Figure 8**), , ranged, with three exceptions, between 2.00 and 10.00 mg/L (**Figure 8, Table 4**). The laboratory qualified 26 values >2 and ≤ 10 with "I" - between the minimum detection limit and the practical quantification limit, and 73 values as "U" –

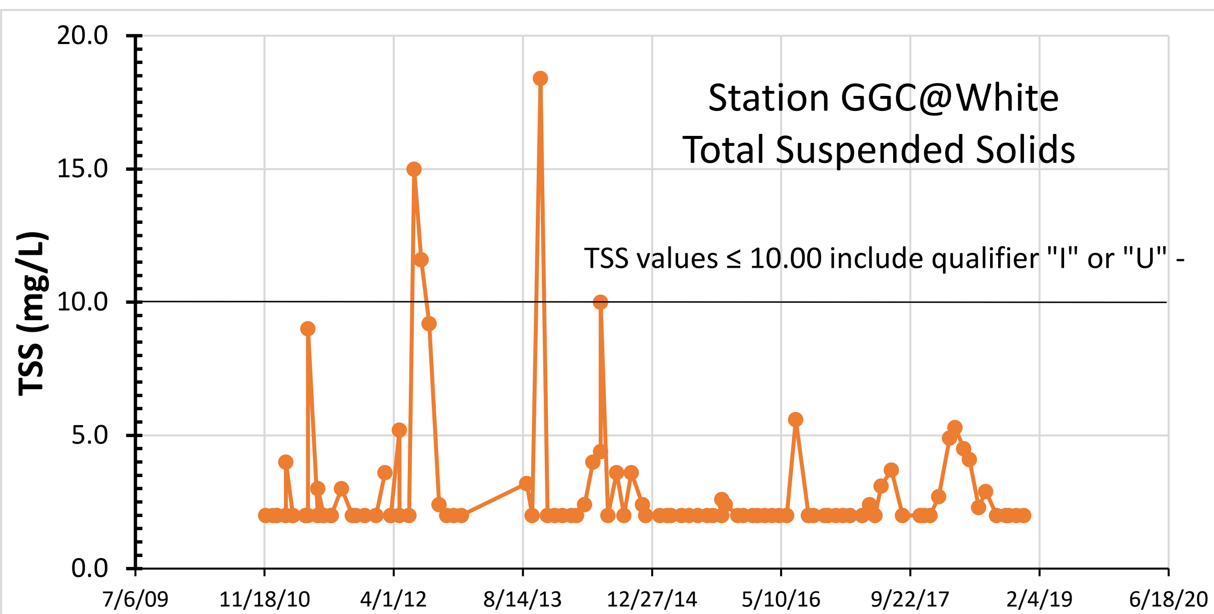

Figure 8. Total Suspended Solids Data from Station GGC@White

below the minimum detection limit of 2.0 mg/L. There was no significant correlation between TSS values and discharge values on the day the samples were collected. Collectively, these data suggest that outside exceptional events, TSS values in the canal are low at most times.

Table 4. Total Suspended Solids Dataset Description

Data Set Description	mg/L	Data n	Comment
ALL GGC TSS data	2.84	101	Includes 76 values below MDL (=2.0 mg/L)
GGC TSS data > 2.0 mg/L	4.90	29	Includes 26 values between MDL and PQL six values above screen criteria (7.0 mg/L)
GGC TSS data ≥ 10 mg/L	15.00	3	All values are above screening criteria (7.0 mg/L)

The average of all data from GGC was selected for use in loading and nutrient removal calculations. Because most of those data are not fully quantified, they should be used with the understanding that this value is associated with an unknown error but is assumed an indication of the typical condition of the canal waters at that location.

The background TSS value for the project area was assumed 2.0 mg/L. The actual value is unlikely to be higher than the values reported in the GGC samples and we cannot estimate a value lower than the minimum detection limit reported in Atkins (2011).

I-75 Runoff Water Quality

The project design includes the use of the I-75 stormwater canal to move water from the GGC diversion point to the project effect area. This will result in some I-75 runoff entering the project inflow waters. Therefore, we have estimated I-75 runoff water quality to allow an evaluation of the water quality from a mixed flow (GGC and I-75 runoff). No water quality data for I-75 runoff at or nearby the project area were available, so literature values of large Florida highway runoff water quality were used to estimate I-75 water quality (**Table 5, Table 6**).

Two data sources provided potential information. ATM (2010) recommended EMC values for FDOT District 1, which includes the project area. Harper and Baker (2007) identified EMC values for runoff of large roadways in South Florida. ATM did not include TSS, which is a critical component of the treatment analysis, since TP is mostly attached to solids. While the values from Harper and Baker (2007) are higher than those from ATM (2010) (**Table 5, Table 6**), they provide a complete dataset for this analysis and will provide conservative loading and treatment estimates for the project

Table 5. Average Water Quality Values, Golden Gate Canal at GGC@White Sampling Station, Naples FL. And comparison to average Florida Roadway EMC Values (**Table 1**)

Parameter	GGC Water Quality (mg/L)	Roadway EMC Water Quality (mg/L))
TP	0.029	0.22
TN	0.914	1.64
TSS	9.391	37.30

Table 6. Stormwater Event Mean Concentration (EMC) values from large Florida Roadways (Harper and Baker 2007)

Sampling Location	Data Source	Average EMC Value (mg/l)		
		TP	**TSS**	**TN**
Broward County (6-lane)	Mattraw, et al. (1981)	0.08	15	0.96
I-95 Miami (Bridge)	McKenzie, et al. (1983)	0.16	42	3.2
Maitland	German (1983)	0.24	27	1.3
I-4 Maitland Interchange	Harper (1985)	0.17	--	1.4
Maitland Blvd.	Yousef, et al. (1986)	0.17	--	1.4
I-4 EPCOT Interchange	Yousef, et al. 1986	0.42	--	3.16
Winter Park I-4	Harper (1988)	0.23	34	1.6
Orlando I-4	Harper (1988)	0.55	66.5	2.15
Bayside Bridge - Tampa	Stoker (1996)	0.1	20	1.1
Tallahassee	ERD (2000)	0.166	70.6	1.1
Orlando - U.S. 441	ERD (2005) Unpublished Data	0.085	23.1	0.683
	Overall Mean Value	**0.22**	**37.3**	**1.64**

Water Quality Summary

Table 6. Water Quality Values for Use in CWIP Project Nutrient Loading Calculations

Parameter	GGC Inflow mg/L	I-75 Runoff mg/L	Wetland Background mg/L
TP	0.29	0.22	0.12
TN	0.914	37.3	0.917
TSS	2.84	1.64	2.0

The data suggest that water quality treatment to reduce nutrients and TSS may be a beneficial project component.

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Collier County Comprehensive Watershed Improvement Plan Project

Supplemental Information Attachment 11: Water Quality Analyses

Section 2. Nutrient Loading and Flowway Treatment

Introduction

The CWIP / Belle Meade Flowway Restoration Project will rehydrate over 9,000 acres of the Picayune Strand State Forest (PSSF) and adjacent lands south of I-75 east of Naples FL. During periods of higher Golden Gate Canal (GGC) flows, water will be pumped from the Golden Gate Canal (GGC) north of I-75 into a channel flowing under I-75 through existing culverts. The water will flow along I-75 for a few miles within an existing stormwater conveyance ditch on the south side of the highway and then into a new stormwater treatment flowway going south into the PSSF where it will terminate in a spreader ditch discharging into the PSSF (**Figure 1**). The water will flow into and benefit hydrologic conditions in at least 9,000 acres of the forest and adjacent wetlands.

The water from GGC will mix with stormwater runoff from I-75, which has significantly higher nutrient concentrations than that of GGC. In order to assess the potential effect of the stormwater on water quality entering the CWIP project area we estimated the I-75 stormwater runoff quality and quantity for the I-75 reach associated with the GGC water inflow path where I-75 runoff would mix with the GGC water. We estimated the concentrations of total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) from the GGC and from the roadway, as well as background concentrations in the Picayune Strand State Forest (PSSF) Project footprint. We then calculated loading from each source independently and loading after mixing of GGC and I-75 runoff.

Estimated Nutrient Loading to the CWIP Project

Water Quality

Estimates of Golden Gate Canal influent water nutrient (total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) concentrations were calculated from Golden Gate Canal long-term monitoring data (**Table 1**; **from Appendix 1**). I-75 runoff water quality (**Appendix 2**) was estimated from reports of large Florida roadway runoff reports (**Appendix 1**: data from Harper and Baker 2007). PSSF background water quality was assumed similar to Big Cypress Basin (BCB) water quality and reported data from BCB (Miller et al 2004) were used for the analysis (**Appendix 1**).

Table 1. Water Quality Values from **Appendix 1** for Use in CWIP Project Nutrient Loading Calculations

Parameter	GGC Inflow mg/L	I-75 Runoff mg/L	Wetland Background mg/L
TP	0.29	0.22	0.13
TN	0.914	1.64	0.917
TSS	2.84	37.3	2.0

Two sources of data were considered to estimate I-75 runoff quality. Event mean concentration (EMC) values for TP and TN recommended for use in FDOT District 1 (ATM 2010), which includes the project area, were compared to similar values for large Florida urban roadways in southern part of the state reported in Harper and Baker (2007). TSS values were reported in Harper and Baker (2007) but not in ATM (2010).(**Table 2**). Because the Harper and Baker set included TSS, critical for the treatment analysis, and that analysis focused on large roads similar to I-75 in the project area, we selected those data, recognizing that they include higher nutrient values than in EMCs focused in the project region. Therefore, the treatment values shown below may provide conservative performance measures.

Table 2. Road Runoff EMC values considered for use in the inflow water quality calculations

Analyte	ATM 2010 (mg/L)	Harper and Baker 2007 (mg/L)*
TP	0.157	0.22
TN	1.16	1.64
TSS	--	37.3
*Selected for Calculations		

The TN concentrations in the GGC are very similar to the TN concentrations reported for the interior of Big Cypress Basin (**Appendix 1**). I-75 Runoff TP concentration is lower than GGC inflow (the roadway includes no significant source of TP).

Annual GGC Canal withdrawal volume

The project simulations resulted in an average 139 day/year operation period over the eight-year simulation period, with an average annual withdrawal from GGC of 2,443,513 m^3 (645.5 million gallons).

I-75 Runoff Volume

Average annual volume contributed by I-75 stormwater runoff (277,533 m^3) comes from the I-75 stormwater canal section that the CWIP will use to move water from GGC to the PSSF. The conservatively high runoff volume for nutrient loading and treatment calculations was calculated with the following assumptions:

- All CWIP inflow (annual average 139-day operating period) occurs during the rainy season.
- Rainy season precipitation accounts for 78% of the total annual rainfall volume.
- I-75 runoff-contributing area = 117.3 acres (474,696 m2).
- Rainfall = 62 inches (1.57 m): Average annual rainfall (from MIKE SHE model input, based on NEXRAD data from 2008 through 2017)
- Runoff Coefficient = 0.42: Average annual runoff coefficient (average of wet season and dry season, assuming type ‘C’ soils Heavy Industrial and Roadway coefficient, from Table A-3 of Sarasota County County-Wide Non-Point Source Pollutant Loading Model (Jones Edmunds, August 2005)
- CWIP rehydration flows will occur for an average of 139 days /year (equal to 91% of the wet season period May 15 – October 14) and 78% of rainfall in the project area occurs during the rainy season (when project rehydration flows will occur).

The CWIP project plans to move water into the PSRP about 139 days year, primarily during the wet season, but with the potential to withdraw water from CCG at other high flow periods as well. Therefore, the estimated volume is a higher value than might often occur, as the calculations assumes that all operations will occur during the wet season.

Project Nutrient Loading to the Picayune Strand State Forest

The average annual loading (kg/year) of phosphorus, nitrogen, and total suspended solids in GGC water withdrawn for PSSF rehydration were calculated as the product of the simulation average annual flow and the GGC nutrient values (**Table 1**). Loads from I-75 runoff were similarly calculated using the roadway runoff volume estimate and the EMC values in **Table 1**.

Inflow Water Quality Treatment

Water will be withdrawn from the GGC north of I75, flow through a newly constructed ditch south to the 75 stormwater ditch and related culverts to pass from the north to the south side of I-75. After traveling for about one mile east in the stormwater canal on the south side of I-75, the water will flow south into the Picayune Strand State Forest in a newly constructed inflow canal. A pump station at the north end of the canal will pump the water south about a mile to a spreader ditch in the forest. Ideally, Collier County would provide water to the forest that has natural system background nutrient and solids concentrations. However, the water from GGC and the I-75 runoff have above-background levels. To improve the inflow water quality, the county has designed in-line treatment of the water to minimize the nutrient and suspended solids in the water entering the forest. The canal leading south from the I-75 pump station to the spreader ditch in the forest is designed as a settling canal. Part of that canal is designed deeper than necessary just to transport the necessary volumes for rehydration. The canal design creates create an in-line sedimentation pond to remove and store suspended solids that settle out of the influent water.

<u>Sedimentation Pond Design</u>

For this analysis we assumed the following definitions

- Sediments (SED): particles with diameter greater than 75 µm
- Settleable solids (SET): particles with diameter 25–75 µm
- Suspended solids (SS): particles with diameter 1.5–25 µm.

The pond was designed to settle materials 25 µm and larger particles for the design flow based on the following:

- Particle specific gravity = 2.0 (Crites and Tchobanoglous, 1998)
- Settling velocity 0.0003 ft/sec (assumes spherical particles) – conservative velocity estimate
- V_s = 0.0004 ft/sec
- Overflow Rate V_0 = Q/A
    - Q = 100 cfs
    - V_0 = 0.00030
- Required Area A = Q/ V_0 = 7.7 acres
- Assuming a safety factor = 1.5

- Required Area A = 11.5 acres with a depth of 6 ft

Sedimentation Pond Nutrient Removal Rates

Table 3. Partitioning of Total Suspended Solids in Roadway Runoff in Florida

	Estimated Wet Detention Removal			
Particle Fraction	**Ying 2007**	**Kim & Sansalone 2008**	**Storm Management Academy 2015***	**Comment**
SED (> 75 µm)	15.3%	19%	17.15%	Available for settling in the canal
SET (25–75 µm)	54.7%	27%	40.85%	Available for removal in sump
SS (1.5–25 µm)	30%	54%	42.00%	40% may settle in the canal (Sansalone & Ying 2009)
*Selected for Calculations				

Ying (2007) and Kim and Sansalone (2008) estimated about 58% of the solids (SED and SET fractions) and 40% of the SS should settle in wet detention area for a total 75% estimated removal of solids from I-75 runoff. Stormwater Management Academy (2015) estimated that wet detention basins should remove 70% of sediments, 45% - 70% of total phosphorus, and 30% - 50% of total nitrogen.

The conveyance system will likely settle large (SED) particles. However, for this analysis we assumed that nutrient treatment would occur only in the in-line treatment area. We used the lower removal rates (70% solids removal, 45% TP removal and 30% TN removal) from the Stormwater Management Academy analysis and modified the inflow channel design from I -75 to the spreader ditch (Figure 1: Treatment Flowway) to create appropriate conditions for solids settling.

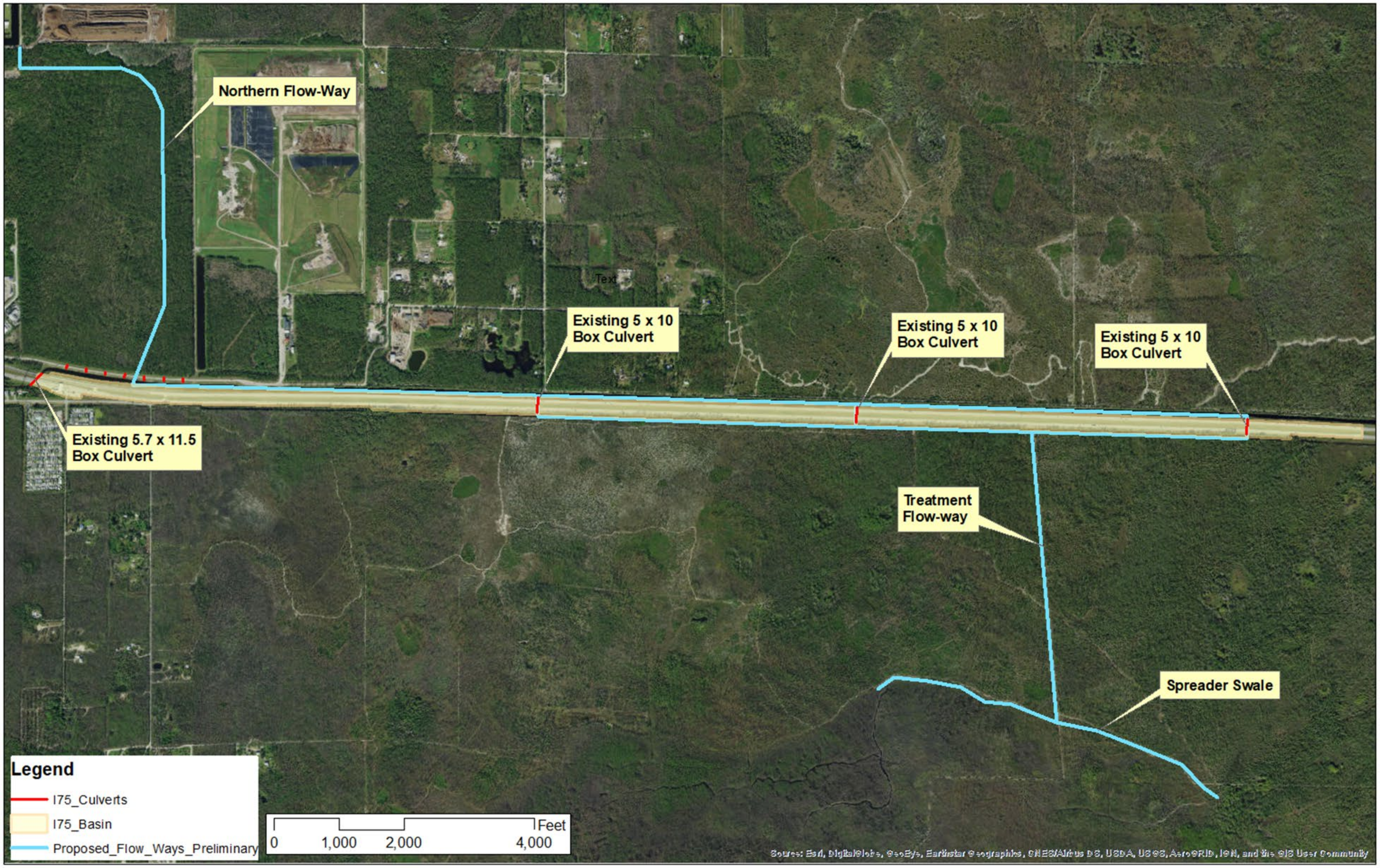

Figure 1. Water Conveyance System from Golden Gate Canal to the Picayune Strand State Forest Rehydration Area

Nutrient Loading and Removal Calculations

Individual nutrient and TSS concentrations and loads from the GCC and I-75 runoff were first calculated as independent sources (if sources flowed into the system without interaction) (**Table 4**: GGC and I-75), assuming a fixed inflow volume with I-75 water replacing GGC water. I-75 loads were based on an annual contributing volume during system operation of 277,533 m^3 (assuming the project captured 100% of the volume) assuming that all runoff capture occurs during the rainy season and a 139 day project operation period. The project may capture 100%@ of the stormwater runoff but will likely capture at least 50% of the runoff in any case.

The net nutrient and TSS loading amounts and concentrations to the PSSF were calculated as the sum of the GGC and I-75 loads divided by the estimated average annual inflow volume (2,443,513 m^3). The roadway runoff volume was presumed to replace, not add to the volume from GGC (not add to the inflow volume) because the inflow volume and rate are controlled by pumps. Loading was also calculated on a square meter basis, assuming a 9,002-acre (36.4 km^2) area of the project would experience long-term changes in hydroperiod and wet season water elevations.

Table 4. Estimated Nutrient Concentrations and Loads of GGC and I-75 sources.

GGC Water Nutrient Concentration and Annual Load			
Parameter	**mg/L**	**kg**	
TP	0.029	70	
TN	0.914	2234	
TSS	2.838	6933	
I-75 Runoff Nutrient Concentrations and Annual Load			
parameter	**mg/L**	**100% Capture (kg)**	**50% Capture (kg)**
TP	0.22	44	22
TN	1.64	325	162
TSS	37.3	7384	3692

The net inflow concentrations and loads (**Table 5**) were calculated by assuming that the I-75 runoff replaced volume coming from GGC. The thus weighted values were used in the treatment system removal estimate. **Table 5** shows pre- and post-treatment values, with the post treatment values representing the water quality reaching the Picayune Strand State Forest and 9,0002 acre project effects area (Nutrient and TSS Loads Entering PSSF After Inflow Canal Treatment). At that point, TN levels are not significantly different the those estimated for the forest waters. TP and TSS concentrations are a little less than twice the predicted background (13 ppb and 2 mg/L). If the system captures only 50% of the I-75 runoff, only TP remains above estimated background concentrations.

Table 5. Nutrient Loading Calculations

Inflow Loads and Concentration Prior to Inflow Canal Treatment Area				
	100% I-75 runoff capture		**50% I-75 runoff capture**	
Parameter	**kg**	**mg/L**	**kg**	**mg/L**
TP	108	0.04	89	0.04
TN	2378	0.97	2306	0.94
TSS	13756	5.63	10345	4.23
Nutrient and TSS Loads Entering PSSF After Inflow Canal Treatment				
	100% I-75 Capture		**50% I-75 Capture**	
parameter	**kg**	**mg/L**	**kg**	**mg/L**
TP	59	0.024	49	0.020
TN	1665	background	1268	Background
TSS	8253	3.38	5690	2.33
Annual Areal Load Over CRA and FE (9002 acres)				
	No Treatment*	**100% I-75 Capture**	**50% I-75 Capture**	
parameter	**mg/m2**	**mg/m2**	**mg/m2**	
TP	3	2	1	
TN	65	46	35	
TSS	378	227	156	
Percent Wetland Removal to Achieve Wetland Background Targets				
	Wetland Background	**% Removal without Treatment***	**% Removal (100% I-75 Capture)**	**% Removal (50% I-75 Capture)**
parameter	**mg/L**	**%**	**%**	**%**
TP	0.013	70.6%	46.5%	35.1%
TN	0.917	5.8%	nominal	nominal
TSS	2.000	64.5%	40.8%	14.1%
*Assumes 100% capture of I-75 runoff				

Discussion

Even if the project captured 100% of the stormwater runoff from the Section of I-75 associated with the inflow channel route, the proposed project design including in-line settling provides effective management of nutrients. In addition, the project includes 9,002 acres of significant wet season hydraulic loading, resulting in a very low areal loading rate of TP, TN, and TSS. With estimated nutrient concentrations close or at background levels entering the forest, the likelihood of nutrient changes in the project area are very low.

If the TP and TN values are in fact lower than those used in the calculations, as the data from ATM (2010) suggest, nutrient concentrations in water entering the forest will be lower than predicted here. The next section of this attachment provides an estimate of expected area of wetland forest necessary to achieve background nutrient concentrations assuming all I-75 volume is captured within the CWIP water conveyance system.

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Collier County Comprehensive Watershed Improvement Plan Project

Supplemental Information Attachment 11: Water Quality Analyses

Section 3. Nutrient Assimilation in the Core Rehydration Area

Introduction

The water entering the Core Rehydration Area will have phosphorus and total suspended solids loads higher than estimated background. Naturally occurring forested wetlands and herbaceous wetlands have been used in Florida as wetland treatment for water quality improvement for many decades (Kadlec and Knight 1996). Calculation of removal performance can be very complex and require large amounts of supporting data. However, there are simple models that may provide some insight into the water quality changes expected once the water from the CWIP conveyance system enters the PSSF. An initial assessment of expected phosphorus uptake in the CRA can be made using a mass balance model with first -order areal uptake (Kadlec and Knight 1996)) for a unidirectional, non-infiltrating constant flow wetland. Within the core rehydration area, these are not unreasonable assumptions at least during the proposed the annual operation period.

Model

$$\frac{C-C*}{Ci-C*} = \exp\left(-\frac{k\mho}{h}y\right) = \exp\left(-\frac{k}{q}y\right)$$

Where C = outlet concentration (µg P L^{-1})
C* = background concentration (µg P L^{-1})
C_i = inflow concentration (µg P L^{-1})
h = wetland free water depth (m)
k = settling rate constant (m d^{-1})
q = detention time (d)
ʊ = fractional distance through the wetland
y = fractional distance through the wetland (non-dimensional)

By rearranging the equation to obtain the outflow concentration C and sequentially altering the parameter y, the necessary fractional distance through the wetland that results in background phosphorus water quality can be estimated. That distance can then be converted to an area to estimate the area of wetland necessary to achieve the target (background) concentration.

Since C* and Ci are already predicted and the outflow concentration target is background (C*), the equation can be written as

$$C = \left(\exp\left(\frac{-k}{q}\,y\right) * 11\right) + 13$$

We assumed the following

- 100% of I-75 runoff would be captured, resulting in the highest expected influent P concentrations.
- The inline treatment system in the north south channel bring water to the PSSF would function to produce influent TP = 24 μg P L^1 (see above)
- A very low settling rate (0.01 m d^{-1}: (See e.g. Kadlec and Knight 1996, Jorgensen and Bendoricchio 2001) was selected assuming that the TP remaining after inline treatment would be the smallest particles (1.5 – 25 um) and some colloidal / dissolved material.
- The spreader ditch that stretches across the entire northern bounty of the core rehydration area would result in sheetflow through the CRA. The landscape of the CRA, dominated by Cypress and Cypress Pine cabbage Palm communities, with similar landscape elevations, suggest this is not an unreasonable assumption.
- The fractional distance y is assumed equivalent to the fractional area of the CRA, as the CRA footprint is roughly rectangular along much of its north-south axis and flows should move relatively uniformly through the cypress dominated area.
- Water depth (0.14 m) equal to the average CRA hydroperiod depth.
- The CRA hydroperiod (139 days)
- Detention time within the CRA treatment area of 2.2 days, calculated as the total primary effects area detention time (8.2 days) times the fraction of the total effects area footprint included in the CRA. This estimate does not account for the fact that the CRA has greater depth and therefore greater volume and retention time that other zones within the project assessment area and the Flowway extent.

Results

The model predicted a minimum fractional distance y = 0.25 (~569 acres of 2,389 CRA acres) to achieve a concentration of 13 μg P L^{-1}.

We did not estimate TSS changes. The influent concentration, estimated as 3.38 mg/L, is very close to background and there are no similar, very simple models for such an estimate.

We recognize that actual system performance may vary from the predictions above. This equation and related coefficients were designed using data very largely of non-forested wetland treatment system performance. The project wetlands are natural (as opposed to constructed treatment wetlands), forested, and much larger than most of the systems studied to develop models of wetland phosphorus uptake. Natural wetland water depths and hydroperiods are most often much more variable than treatment wetlands. However, given the area within the CRA and the primary effects area (over 9,000 acres), the analysis suggests that water flowing through the system will reach background TP concentrations well before it reaches the southern end of the freshwater wetlands being rehydrated. In addition, the influent TP concentrations are relatively low; vegetation community changes within the treatment area, dominated by cypress and Cypress pine cabbage palm FLUCCS communities are likely to be minimal; similar systems in Florida have been in use for water quality treatment of much higher TP loads and concentrations, for very long periods (decades) most often without the “resting time” that occurs in the CWIP project area for over ½ the year when the water recedes below the soil surface.

Collier County built and is operating a long-term monitoring program including constant water level monitoring and annual vegetation monitoring at 60 stations and quarterly water quality monitoring at 20 stations within the project area. These data will provide allow the county to closely track system performance and adapt operations should the project performance be at variance with the predictions. The county has developed an adaptive management plan to ensure the safe and beneficial long-term project performance, coordinating with their agency stakeholders on a regular schedule to review the project performance and obtain consensus for adaptive changes to their operations Collier County is committed to the high level of effort necessary to ensure that the long-term result of this project is beneficial to the environment, the county, and the state of Florida. With their efforts, Collier County will also be contributing to the science of forested wetland restoration, a relatively little-studied component of Florida’s natural environment.

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